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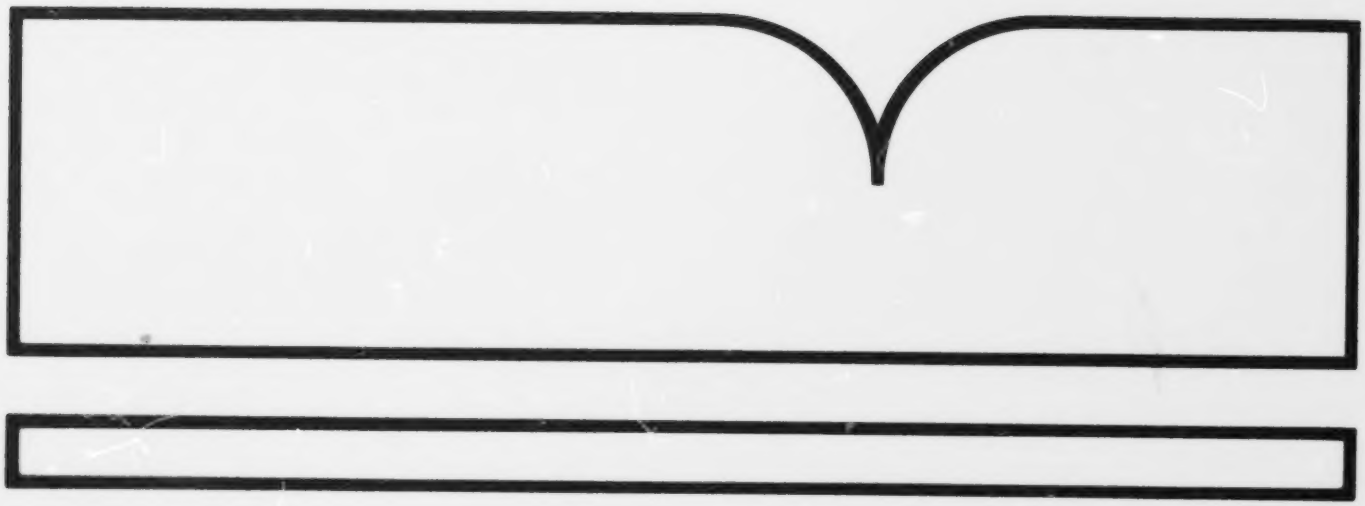

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16. ABSTRACT

The cumulative impacts component of EPA's wetlands research arises from a concern that many individual permit applications for wetland alteration involve seemingly minimal change, yet collectively their impact may be significant. Numerous studies have documented the potential benefits of individual, natural wetlands for passively performing landscape functions - such as water purification, maintenance of desirable streamflow regimes, and habitat. However, the cumulative (or regional) effects on these functions of landscapes dominated by forested wetlands (as apposed to those dominated by other natural cover types) have received only limited attention. EPA's interest in these topics in not merely academic; it is strongly oriented toward providing accurate technical information necessary for an effective regulatory program.

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DETERMINING THE CUMULATIVE EFFECTS OF FORESTED WETLANDS: EPA'S RESEARCH PROGRAM, AND CHOICES FOR RESEARCH AND MONITORING DESIGNS

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I. BACKGROUND

The Wetlands Research Program of the U.S. Environmental Protection Agency (EPA) has focused on three major topics: Mitigation, Cumulative Impacts, and Water Quality (51). Research on these topics in many regions of the country is being coordinated, under the direction of Dr. Eric M. Preston, through EPA's Environmental Research Laboratory in Corvallis, Oregon. The research is conducted by EPA staff and on-site contractors at EPA's research facilities in Corvallis and Duluth, Minnesota, as well as by universities and other government agencies under various funding agreements.

The Cumulative Impacts component of EPA's wetlands research arises from a concern that many individual permit applications for wetland alteration involve seemingly minimal change, yet collectively their impact may be significant (36). Numerous studies have documented the potential benefits of **individual**, natural wetlands for passively performing landscape functions -- such as water purification, maintenance of desirable streamflow regimes, and habitat. However, the **cumulative** (or "regional") effects on these functions of **landscapes** dominated by forested wetlands (as opposed to those dominated by other natural cover types) have received only limited attention. For example, although a few studies of effects of forestry on Southeastern water quality have been conducted (see reference 42), the effects of different proportionate acreages of wetlands upon nonpoint-source runoff, and ultimately the water quality at the outlet of the "watershed" unit of a landscape, is uncertain and cannot be assumed to be either detectable or linear.

EPA's interest in these topics is not merely academic; it is strongly oriented toward providing accurate technical information necessary for an effective regulatory program. A fairly small EPA regulatory staff annually reviews over 9000 applications for wetland alteration, and cannot afford to collect extensive, site-specific data before making each regulatory decision. Although techniques are being developed and tested for rapid assessment of the functions of individual wetland tracts (e.g., 1; 3), and for predicting the impacts of specific project activities to some of these functions, there are few methods that allow for assessing and ranking **regional landscapes** based on (a) their wetlands' collective and relative effectiveness, and the (b) overall sensitivity of the landscape to the effects of cumulative wetlands loss.

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A major goal of EPA's research on inland wetlands is to develop a technically-supported, synoptic method for a risk-based categorization of landscapes. Explicit in the design of this method is that it be capable of utilizing data that are generally available throughout the country; that it perform the analysis relatively quickly and inexpensively; and that the analysis address broad-scale questions concerning cumulative impacts. With these requirements in mind, the EPA Wetlands Research Program at the Corvallis Laboratory has been evaluating one type of synoptic approach -- a rapid, manually-executed procedure that involves making a few simple measurements from topographic maps and plotting widely-available data on watershed maps. This has been applied, as an operational draft, to four watersheds: the Upper Illinois in Illinois and Indiana, the Upper Mississippi in Minnesota, the Cache in Arkansas, and the Pearl in Mississippi.

EPA is, of course, concerned with the scientific credibility of rapid assessment approaches. Developing the technical underpinnings of synoptic assessment methods requires that the following questions be addressed through a research effort:

(1) Of the various landscape factors which can affect landscape function, is the cumulative effect of **wetlands** statistically detectable? If so, **how** important are wetlands, as opposed to other landscape features?

(2) If wetlands cumulatively affect landscape function, by **what mechanism** do they do this? Does an effect occur simply because wetlands represent a lack of pollution sources, or because they collectively act as a "sink" for polluted runoff?

(3) If wetlands cumulatively affect landscape function, are some **types** more important than others to riverine water quality, floodflow, or regional biodiversity?

In planning for a cumulative effects research program, an initial challenge was to identify research strategies which could be used to address these questions given the constraints of EPA's wetlands research budget. Another important consideration was that the research results be developed rapidly, in time to address the significant rate of wetlands loss occurring in some regions. At a workshop in 1987, EPA solicited suggestions from wetland scientists regarding possible strategies for Cumulative Impacts research (40). At the workshop and in subsequent discussions several possible strategies emerged. Five of these are the subject of this presentation. Although these strategies are discussed in the context of wetlands, research managers with responsibility for other resources or activities related to cumulative effects might encounter similar choices and considerations in designing research and monitoring programs.

II. RESEARCH STRATEGY CHOICES

A. Landscape-Impact Description Strategy

A number of available "cumulative impact methods" consist of procedural guidelines or qualitative models for **identifying** likely cumulative impacts. However, these methods sometimes go no further than (a) providing checklists of considerations which must be addressed or procedures which should be followed (e.g., 11, 46, 24, 5, 12), and/or (b) providing maps of sensitive features (e.g., 50, 16), and/or (c) describing or mapping wetland trends, based sometimes on the number and types of permits which have been issued within a functional unit of the landscape (e.g., 14) and associating this with wetland losses measured from aerial photographs (e.g., 45), and/or (d) identifying impacts which might occur and might be cumulative, based on conceptual models which can identify pivotal factors and contain many linkages and assumptions (6, 31, 43, 30).

All of these approaches require subjective inputs, from the resource manager and/or the public, to answer their questions and to infer the sources of cumulative impacts. Because these approaches generally do not collect or extensively analyze "data", in the sense of measuring dependent and independent variables and testing quantitative thresholds, they provide little technical substantiation of the occurrence of cumulative impacts. For example, compilations of permit records and/or wetland loss rates can be used to document the fact that impacts have occurred, but do not ascribe causality or describe consequences of impacts to landscape functions. When conceptual models are used, the procedures for aggregating their individual linkages into an overall system response are sometimes very detailed and systematic, but the technical support for these linkages and assumptions is often based on anecdotal accounts of individual (and possibly unrepresentative) linkages and systems, with the assumption that these can be aggregated to describe cumulative response.

In summary, the Landscape-Impact Description strategy, while potentially useful for rapid, qualitative assessment of cumulative impacts and for initially characterizing a system and generating hypotheses, provides little supportable information about causality or consequences.

B. Deterministic Modeling.

This strategy involves using landscape-level, quantitative, mechanistic models to determine the response of landscape functions such as water purification, maintenance of desirable streamflow

regimes, and habitat (the dependent variables), to changes in wetland extent or pattern (the independent variable). Several types of watershed models with potential applicability to wetlands are available (33,10). Models are often used in a gaming sense, and have been applied in simulation exercises to multiple combinations of hypothetical (but realistic) landscapes containing a variety of wetland or disturbance patterns (e.g., 15, 17, 37, 7). This approach has the advantage that a virtually limitless number of scenarios can be examined quickly. Outputs from the scenario testing can subsequently be clustered into discrete categorizations of various landscape or perturbation "types" which appear to be most favorable for a particular desired environmental condition or threshold. Land managers could then protect or enhance these landscape types or features so as to optimize their particular values (e.g., 47).

However, several problems arise. First, there are very few deterministic models available which operate at regional scales, except perhaps some with surface water themes. For example, watershed models such as HSPF, TR-20, and HEC (18) might be used to simulate the effects on peak flow of storage loss; the WASP series (4) might be used to examine scenarios relating wetland changes to changes in contaminant transport; and regional models (48), such as those being developed as part of planning for global climate change, might be used for both. Several deterministic models potentially useful for cumulative effects simulation are described by (25). However, the applicability of all of these models specifically to wetland landscapes is unknown. Especially in the case of predicting the water purification function, certain unique features of wetlands may invalidate the conclusions of models developed primarily for other surface water types.

Although models relevant to wetlands have been developed (surface water models of (28, 22; waterfowl energetics models of 19), they generally operate at the level of the individual site, do not account for interactions among wetlands or between wetlands and other landscape elements, and/or require immense inputs of detailed field data, thus limiting their use in simulation exercises. Moreover, use of models in a simulation mode may require numerous simplifying assumptions, not all of which are easily discernable to the researchers doing the simulations or the wetland managers who use the final outputs. Situations where model application would yield inaccurate results may be difficult to define precisely. In summary, the Deterministic Modeling strategy is usually very data-intensive, subject to unknown and unknowable aggregation errors, and limited by knowledge of wetland-specific processes.

C. Landscape Manipulation.

This strategy involves intentionally altering or manipulating

wetlands in multiple watersheds (or other landscape units) and simultaneously measuring the effects of various types of singular and multiple alterations, under various sequences, on various combinations of wetland types. Because it involves dose-response experimentation, this strategy provides the most conclusive proof of the role of wetlands in the watersheds studied. However, it has several drawbacks.

First, the intentional alteration of wetlands, if irreversible, may raise several legal and ethical questions, even if confined to a small area. Second, several landscape factors, such as climate and soil type, are not amenable to manipulation, and the manipulation of others, while feasible at the individual-site level would be extremely costly on a watershed-wide basis. Thus, applicability of the conclusions to other areas may be limited. Third, since wetlands and precipitation are highly dynamic, studies should be conducted over several years, perhaps decades. However, the urgency of wetland loss implies that regulators cannot wait so long for results.

D. Ongoing Monitoring.

This strategy involves measuring both wetlands (the independent variable) and landscape functions such as water purification, maintenance of desirable streamflow regimes, and habitat (the dependent variables). Ideally, a "BACI" design (before-after, control-impact; 44) is used, in which treated and untreated wetlands are measured both before and after a potentially impacting activity has occurred, and empirical data are then examined statistically. In order to maximize the ability to extrapolate from results, large sample sizes (i.e., large sets of wetlands, multiple time frames) are preferred, but a review of published literature suggests they seldom have been affordable.

The Ongoing Monitoring strategy differs from the Landscape Manipulation strategy in that (a) study areas are chosen opportunistically rather than intentionally, i.e., wherever applications have been made by developers to alter wetlands, and, (b) the independent variables are "manipulated" (with no particular scientific purpose) by the developer, rather than the scientist. Because of this, researchers normally will have less ability to influence the nature and location of impacts to wetlands in such watersheds, and statistical controls will be looser and data more difficult to interpret. Also, analysis of data from such studies may be dictated by the speed and manner in which developers choose to alter the wetlands. This poses tough conflict-of-interest questions for researchers, as well as possibly delaying conclusions about cumulative effects thresholds.

Nonetheless, the Ongoing Monitoring strategy is relatively inexpensive and can provide useful information not only about the

cumulative effects of wetlands, but also about the cumulative effects of development on wetlands (49). Research efforts which are using or have used this strategy include a study of silvicultural effects at a 32-hectare site on water quality in Alabama (32); an EPA-sponsored study of 30 Minnesota wetlands; a study of wetlands used for stormwater treatment in King County, Washington; studies of Florida wetlands used for wastewater treatment and Pennsylvania wetlands exposed to mine drainage.

E. Statistical Analysis of Existing Data.

This strategy is similar to the above, but relies on **existing** data sets rather than collecting new monitoring data as part of a specific wetland development study. It, too, supplies a circumstantial case for the cumulative effects of wetlands, using multivariate statistical techniques to analyze the data. Because no new field data are collected, cost savings are realized and these can be redirected toward increasing the sample size, e.g., number of watersheds examined. This ultimately may lead to increased statistical rigor and an ability to extrapolate the results to a broader area. Also, by relying on existing data sets (particularly stream gauging records, in the case of wetland cumulative effects on downstream hydrology), the period of record may be sufficient to account for wetland and climate dynamics. To efficiently compile existing spatial data, Geographic Information Systems (GIS) can be used (38, 26). Once empirical models have been developed, the GIS can be used to apply the models to watersheds not included in the original analysis, provided that those watersheds are generally similar to those from which the empirical models were built, and that watersheds used to build the empirical models were randomly selected to represent the population of all watersheds in the region of interest.

Sources of regional and national trends data which may be used in such analyses are summarized in (2). However, most such data are drawn from river sampling stations in watersheds, rather than from individual wetlands, so they may be used only to examine the effects **of** wetlands on riverine conditions, and not the impacts of human activities **upon** wetlands. EPA's proposed "Environmental Monitoring and Assessment Program (EMAP) represents one means of solving this information need as it collects data from a national network of wetlands in both natural and disturbed landscapes. The EPA Wetlands Team, in collaboration with the University of Florida, has been preparing for this effort by testing field measurement techniques for forested wetlands, and by preparing a 1990 report on biomonitoring and bioindicators in forested wetlands.

The strategy of inferring cumulative effects of wetlands by analyzing extensive, landscape-level data sets appears to have been first used in studies of the cumulative effects of wetlands on flood storage and water quality in Wisconsin (13, 34), and later

(2) To protect quality of surface waters and their aquatic life, buffer zones should be at least X feet long or Y feet wide.

(3) To restore regional wetland biodiversity, wetlands should be constructed at a density of X wetland acres per square mile, at location types A, B, or C, and should be of type I, J, or K.

(4) Loss (to filling or drainage) of X percent of the wetlands in watershed type A will cause violation of standards for ambient water quality, and losses to the native fish community, over a distance of Y miles downstream.

(5) Wetlands of types A, B, and C at locations X, Y, and Z are the most deserving of protection (e.g., through acquisition programs or as designated "Outstanding Natural Resource Waters"), based on their exceptionally high expected level of functioning.

(6) To best replace wetland function and be self-sustaining, constructed wetlands in county X should be situated at location A, B, or C and should be of type I, J, or K.

Information such as this will be invaluable for supporting regionalized versions of national-level, rapid assessment methods, and can be used to monitor the national goal of "no net loss of wetland function".

Regional differences among wetlands can be very important, so future studies of this nature in additional regions are desirable. However, with very limited program resources, such studies will probably need joint federal-state (or federal-private) funding, comprehensive wetland and land cover maps which are completely digitized, and extensive data sets (particularly, those covering long time periods, so that the change in wetland acreage is likely to exceed the measurement error associated with measuring trends in wetlands and their related dependent variables). Until results of such regional studies are available, programs intended to monitor cumulative effects of forested wetland alteration will provide the most useful information if (a) measurements are made on a relatively large, heterogeneous set of watersheds (or other landscape units, as appropriate for the dependent variables of interest), (b) wetlands and other land cover types are regularly photointerpreted and digitized using a GIS, and (c) variables are selected for measurement based on knowledge of their likely relationship to wetland impacts.

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